ISSN (print) 0093-4666 © 2013. Mycotaxon, Ltd. ISSN (online) 2154-8889

MYCOTAXON

http://dx.doi.org/10.5248/126.97

Volume 126, pp. 97–108 *October–December 2013*

Ambomucor gen. & spp. nov. from China

Ru-yong Zheng* & Xiao-yong Liu

State Key Laboratory of Mycology, Institute of Microbiology, Chinese Academy of Sciences, Beijing 100101, China

* Correspondence to: *zhengry@im.ac.cn*

Abstract — *Ambomucor* is described as a new genus containing *A. seriatoinflatus* sp. nov. (type), *A. seriatoinflatus* var. *brevior* var. nov., and *A. clavatus* sp. nov. Morphological characteristics for recognizing and differentiating these new taxa are discussed, and full descriptions, line drawings, and a key to taxa are provided.

Keywords — taxonomy, morphology, *Mucorales,* new species, new variety

Introduction

In the summer of 2003, an interesting mucoraceous fungus was isolated from a soil sample collected in Inner Mongolia. Morphological examination revealed the fungus to represent a new species *Ambomucor seriatoinflatus*, described here as the type species of a new genus, *Ambomucor*. One month later, a second strain of this new genus was isolated from Xinjiang Province and is described here as a new variety of the type species, *A. seriatoinflatus* var. *brevior*. In addition, a fungus from Inner Mongolia, originally identified as *Zygorhynchus moelleri* Vuill., is described here as new species, *A. clavatus*. Since then, another new species (from a dung sample collected in Tibet) and another new variety of *A. seriatoinflatus* (eleven strains from Tibet, and one from Shaanxi Province) have been found by the second author, to be described elsewhere.

Materials & methods

Isolations

Fungi were isolated from soil samples using the soil plate method of Warcup (1950).

Cultures

Living cultures of the three taxa studied are preserved in the Culture Collection of the State Key Laboratory of Mycology (with an "Am-" prefix) and the China General

Microbiological Culture Collection Center (with a "CGMCC-" prefix). Dried cultures of the type strains are deposited in the Herbarium Mycologicum Academiae Sinicae (HMAS). These culture collections and herbarium all belong to the Institute of Microbiology, Chinese Academy of Sciences, Beijing, China.

Media & cultivation

Modified SMA (Hesseltine's modified synthetic *Mucor* agar: dextrose 20 g, asparagine 2 g, KH_2PO_4 0.5 g, $MgSO_4 \cdot 7H_2O$ 0.25 g, thiamine chloride 0.5 mg, agar 20 g in 1000 mL distilled water, pH 7; Hesseltine & Ellis 1973) and PDA adjusted to pH 7 were used for morphological studies. PDA adjusted to pH 7 was also used for establishing temperature-growth relationships and for mating experiments. Cultivation period and temperature were (i) 5–7(–10) days at 18–20°C for morphological studies; (ii) 4–7 days at 25–37°C for determining the temperature maximum; and (iii) 7–14 days at 18–25°C for mating experiments.

Results

Maximum growth temperature

The three *Ambomucor* strains described in this paper were tested twice for their maximum growth temperature. The maximum growth temperatures of both *A. seriatoinflatus* var. *seriatoinflatus* and *A. seriatoinflatus* var. *brevior* are 30°C and that of *A. clavatus* is 33°C. As shown by our studies on *Cunninghamella* (Zheng & Chen 2001) and *Rhizopus* (Zheng et al. 2007), different varieties of the same species have a similar maximum growth temperature, while different species have different ranges of maximum growth temperature.

Mating experiments

The 16 living cultures of *Ambomucor* were crossed in all combinations, but zygospores were not produced.

Morphological studies

Within the *Mucorales,* the new genus is morphologically unique in producing two kinds of sporangia (fertile and non-fertile) on the same or different sporangiophores. The fertile sporangia are multispored and columellate, similar to those in the *Mucoraceae.* Aborted sporangia, which occur in short to long chains, are vesicle-like, produce no spores, and lack a columella.

Taxonomy

Ambomucor is distinguished from all other genera of the *Mucorales* (Alexopoulos et al. 1996, von Arx 1982, Benny & Benjamin 1991, Hesseltine 1955, Hesseltine & Ellis 1973, Tai 1979) in having simultaneously two kinds of sporangia: fertile and aborted. We include *Ambomucor* in the *Mucoraceae* based mainly on the characteristics of the fertile sporangia as well as its close relationship with the genus *Zygorhynchus,* also in *Mucoraceae*.

Characteristics for dividing species or varieties in *Ambomucor* include 1) growing or not growing above 30°C, 2) sporangiophore branching patterns, 3) sporangial

size and shape, 4) number of aborted sporangia in a chain, 5) presence or absence, place of origination, and sterile outgrowths that may or may not be spirally twisted from the sporangiophores bearing aborted sporangia, 6) size and shape of the columellae in the fertile sporangia, 7) sporangiospore size and shape, and 8) chlamydospore presence or absence.

Ambomucor R.Y. Zheng & X.Y. Liu, **gen. nov.**

MycoBank MB 518101

Differs from all known genera in the *Mucorales* by possessing both fertile and aborted sporangia simultaneously on the same or different sporangiophores.

Type species: *Ambomucor seriatoinflatus* R.Y. Zheng & X.Y. Liu

Etymology: *Ambomucor*, referring to the presence of two kinds of sporangia.

Mycelia branching, nonseptate when young, septate in age, with aerial hyphae. Stolons absent. Rhizoids scanty, simple or branched, not opposite sporangiophores. Sporangiophores arising directly from substrate mycelia or from aerial hyphae, simple or more usually branched, of 3 main types: (1) bearing normal fertile sporangia only, (2) bearing aborted sporangia only, (3) bearing both fertile and aborted sporangia on the same sporangiophore. Aborted sporangia either borne terminally on the main axes or branches of the sporangiophores or repeatedly proliferating terminally or laterally many times, transferring their contents forward to form chains of aborted sporangia until a fertile sporangium is formed. Fertile sporangia borne terminally on the main axes or branches of the sporangiophores, globose to somewhat depressed-globose, non-apophysate, breaking or deliquescing, dark brown after mature. Columellae well developed but only in fertile sporangia. Sporangiospores also forming only in fertile sporangia. Chlamydospores present. Zygospores unknown.

Ambomucor seriatoinflatus R.Y. Zheng & X.Y. Liu, **sp. nov.** Figs 1, 2

MycoBank MB 518102

Differs from all known species of *Mucorales* by simultaneously possessing both fertile and aborted sporangia on the same or different sporangiophores.

Type: People's Republic of China. Inner Mongolia, Taipusiqi, 41.934593°N 115.282116°E, soil, 16 July 2003, Xiao-yong Liu (**Holotype** HMAS 84258—1; ex-holotype culture CGMCC 3.6665 = Am-1; GenBank AY743664. **Isotypes** HMAS 84258—2–8).

Etymology: *seriatoinflatus*, referring to the chains of aborted sporangia.

Colonies on SMA and PDA at first subfloccose, then granulate, filling the Petri dish in 6–7 (SMA) or 5–6 (PDA) days at 18°C, about 1–3 mm high, at first white, then 'Drab Gray' to 'Light Gray' (Ridgway XLVI), reverse cream to light yellowish brown. Hyphae branching, nonseptate when young, septate

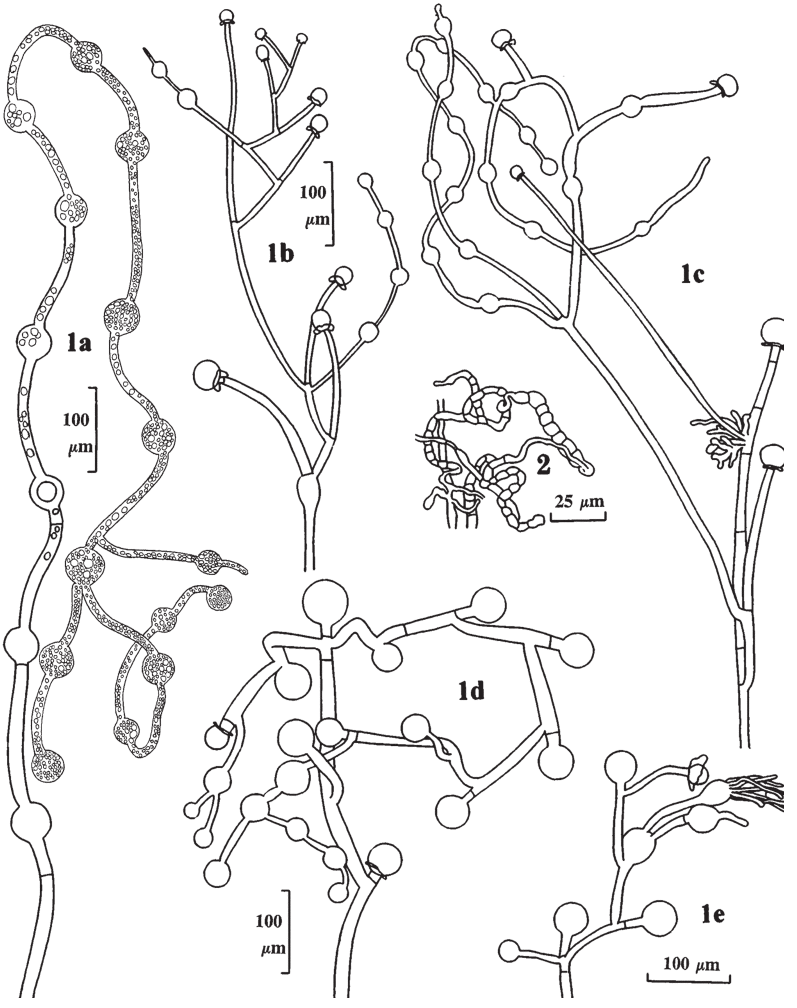

Figure 1. *Ambomucor seriatoinflatus* var. *seriatoinflatus* (AS 3.6665, = Am-1, ex-holotype). 1. Upper portions of sporangiophores showing various kinds of constructions: (a) a long chain of aborted sporangia with intercalary sporangiophores formed between two aborted sporangia; (b) both fertile and aborted sporangia are formed on the same sporangiophore, note that the aborted sporangia are in short chains; (c) same as (b) except that the aborted sporangial chains are longer, also that rhizoids are formed at the base of a sporangial branch; (d) similar to (b) and (c) by forming both fertile and aborted sporangia on the same sporangiophore except that aborted sporangia are much more abundant than the fertile sporangium and the sporangiophore branches usually do not originated from the tip of the former aborted sporangium; (e) a branched sporangiophore similar to (b), (c), and (d) by forming both fertile and aborted sporangia on the same sporangiophore except that rhizoids are formed at the apex of one of the aborted sporangia. 2. Chlamydospores formed on the substrate mycelium.

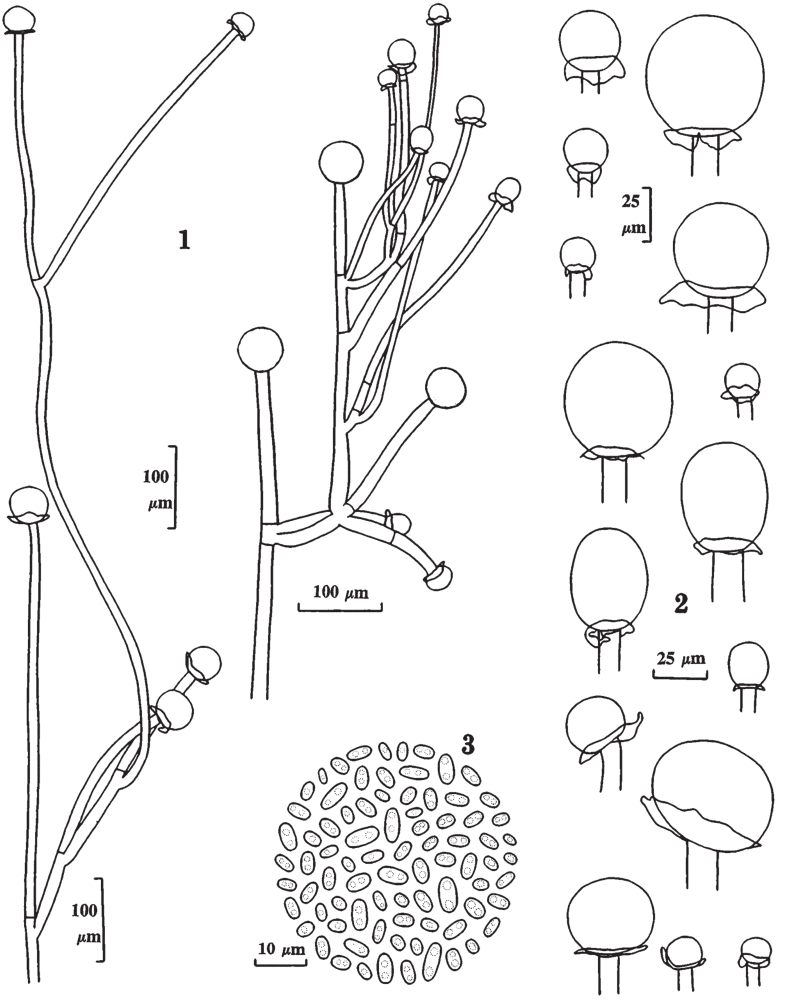

Figure 2. *Ambomucor seriatoinflatus* var. *seriatoinflatus* (AS 3.6665, = Am-1, ex-holotype). 1. Upper portions of sporangiophores, with fertile sporangia only. 2. Columellae of various shapes, all with a small collar. 3. Sporangiospores.

in age, (1.5–)7–14(–18.5) μm diam. Stolons absent. Rhizoids scanty, not opposite sporangiophores; arising from various parts of the sporangiophores or the aborted sporangia. Sporangiophores erect or recumbent, arising directly from substrate or aerial hyphae, of 3 main types: (1) bearing only

normal fertile sporangia, (2) bearing only aborted sporangia, (3) bearing both fertile and aborted sporangia on the same sporangiophore; main axes of the sporangiophores rarely simple, usually branched, 9–18.5(–22) μm diam.; primary branches 1–4(–10), single, in pairs, remaining simple, more often branching monopodially or pseudo-verticillately, sometimes zigzag and branching up to 7 times, (35–)98–437(–1000) μm long, 4.5–13(–18) μm diam., rarely subcurved, usually equal or subequal in width throughout, sometimes slightly subequal in width throughout, sometimes slightly narrowed just beneath the terminal sporangia, hyaline to pale greenish brown, with or without granular contents, becoming vacuolated in age. Septa in main axes and branches of the sporangiophores usually present at the place of branching, sometimes without definite position. Aborted sporangia may also form terminally on the main axes and branches of sporangiophores, or may repeatedly proliferate terminally or laterally, forming intercalary sporangiophores between two aborted sporangia up to 20 times or more, transferring their contents forward to form a short or long chain of aborted sporangia until formation of a fertile and normal sporangium, globose and (18.5–)32–69 μm diam., or slightly elongate when proliferated, granular when young, vacuolate in age, subhyaline. Fertile sporangia borne terminally on the main axes or branches of the sporangiophores, globose, (14–)26–64(–88) μm diam.; non-apophysate, breaking or slowly dissolving, thin-walled, dark brown when mature, broken pieces of wall pale grayish brown. Columellae formed only in fertile sporangia, well developed, very regular in shape, larger ones mostly globose and 16–51(–60) μm diam., or ovoid to ellipsoid-ovoid and (21–)37–55 × (19–)32–48.5 μm diam., smaller ones depressed-globose to sub-applanate and 11.5–51 × 15–64.5 μm, hyaline, some with grayish to brownish contents, smooth, regularly with a distinct collar. Sporangiospores forming only in fertile sporangia, ellipsoid to oblong-ellipsoid, (2.5–)3.5–7 × (1.5–)2–2.5(–3.5) μm, (1–)2 guttulate, hyaline, grayish in mass, smooth, becoming vacuolated in old cultures. Sterile outgrowths usually absent. Chlamydospores rare, single, in short chains, or in small masses, subglobose, ovoid or irregular, 5–9 × 4–7 μm, hyaline to yellow. Zygospores unknown.

Ambomucor seriatoinflatus* var. *brevior R.Y. Zheng & X.Y. Liu, **var. nov.** Figs 3, 4

MycoBank MB 518103

Differs from *Ambomucor seriatoinflatus* var. *seriatoinflatus* by its shorter sporangiospores that in turn have much shorter, curved, verticillate branches.

Type: People's Republic of China. Xinjiang, a glacial valley, 43.648994°N 85.117264°E, soil, 3 August 2001, Xing-zhong Liu (**Holotype** HMAS 89521—1; ex-holotype culture CGMCC 3.6784 = Am-2; GenBank KC108739. **Isotypes** HMAS 89521—2–8).

Etymology: *brevior*, referring to the shorter sporangiospores.

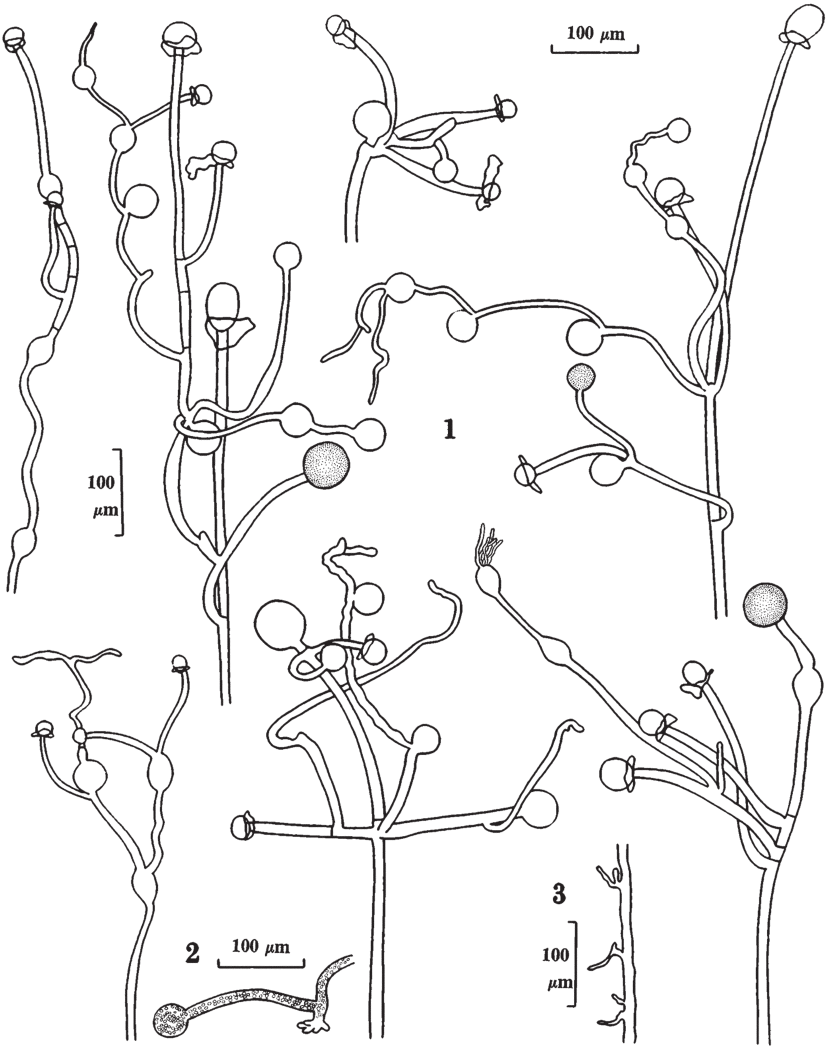

Figure 3. *Ambomucor seriatoinflatus* var. *brevior* (AS 3.6784, = Am-2, ex-holotype). 1. Upper portions of sporangiophores, with both fertile and aborted sporangia on the same sporangiophore. Note that the aborted sporangia are mostly in short chains, also that rhizoids are formed at the apical portions of some of the aborted sporangia. 2. Short and finger-like rhizoids formed at the base of the sporangiophore. 3. Simple or branched rhizoids formed on one side of a sporangiophore.

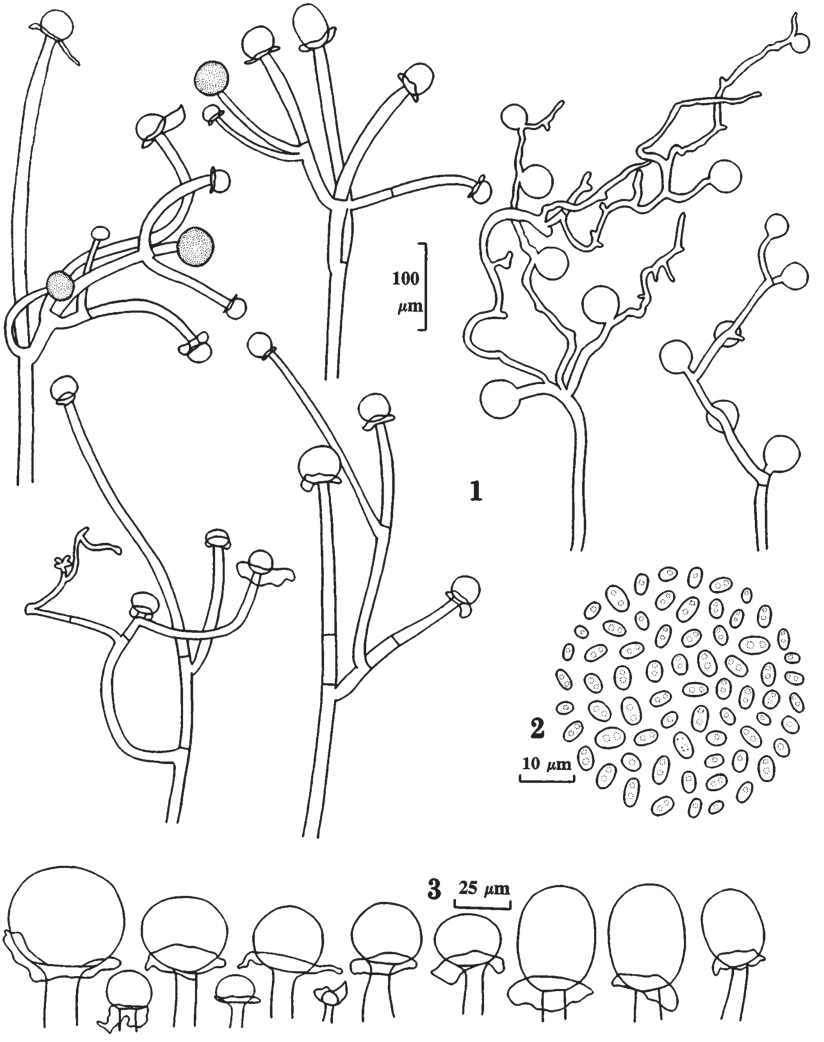

Figure 4. *Ambomucor seriatoinflatus* var. *brevior* (AS 3.6784, = Am-2, ex-holotype). 1. Upper portions of sporangiophores, mostly with fertile sporangia, some with aborted sporangia only. Note that sterile outgrowths as well as septa may be formed on some of the sporangiophores. 2. Columellae of various shapes, all with a small collar. 3. Sporangiospores.

Colonies on SMA and PDA at first subfloccose, then granulate, filling the Petri dish in 6–7 (SMA) or 5–6 (PDA) days at 18°C, about 1–3 mm high, at first

white, then 'Drab Gray' to 'Light Gray' (Ridgway XLVI), reverse cream to light yellowish brown. Hyphae branching, nonseptate when young, septate in age, (1.5–)7–14(–18.5) µm diam. Stolons absent. Rhizoids scanty, not opposite sporangiophores; arising from various parts of the sporangiophores or the aborted sporangia. Sporangiophores erect or recumbent, arising directly from substrate or aerial hyphae, of 3 main types: (1) bearing normal fertile sporangia only, (2) bearing aborted sporangia only, (3) bearing both fertile and aborted sporangia on the same sporangiophore; main axes of the sporangiophores rarely simple, usually branched, curved to subcurved, 9–18.5(–22) µm diam.; primary branches 1–4(–10), verticillately branched, (35–)98–437(–500) µm long, 4.5–13(–18) µm diam., curved to subcurved, usually equal or subequal in width throughout, sometimes slightly subequal in width throughout, sometimes slightly narrowed just beneath the terminal sporangia, hyaline to pale greenish brown, with or without granular contents, becoming vacuolated in age. Septa in main axes and branches of the sporangiophores usually present at the place of branching, sometimes without definite position. Aborted sporangia may also borne terminally on the main axes and branches of sporangiophores, or may repeatedly proliferated terminally or laterally, forming intercalary sporangiophores between two aborted sporangia, up to 20 times or more, transferring their contents forward to form a short or long chain of aborted sporangia until formation of a fertile and normal sporangium, globose and (18.5–)32–69 µm diam., or slightly elongate when proliferated, granular when young, vacuolated in age, subhyaline. Fertile sporangia borne terminally on the main axes or branches of the sporangiophores, globose, (14–)26–64(–88) µm diam.; non-apophysate, breaking or slowly dissolving, thin-walled, dark brown when mature, broken pieces of wall pale grayish brown. Columellae formed only in fertile sporangia, well developed, very regular in shape, mainly depressed globose to applanate, sometimes oblong-ovoid, rarely globose, hyaline, some with grayish to brownish contents, smooth, regularly with a distinct collar. Sporangiospores forming only in fertile sporangia, ellipsoid to oblong-ellipsoid, (2.5–)3.5–5 × (1.5–)2–2.5(–3.5) µm, (1–)2-guttulate, hyaline, grayish in mass, smooth, becoming vacuolated in old cultures. Sterile outgrowths absent or rarely present and zigzag when present. Chlamydospores rare, single, in short chains, or in small masses, subglobose, ovoid or irregular, 5–9 × 4–7 µm, hyaline to yellow. Zygospores unknown.

Ambomucor clavatus R.Y. Zheng & X.Y. Liu, **sp. nov.** Fig 5

MycoBank MB 518402

Differs from *Ambomucor seriatoinflatus* by its ellipsoid aborted sporangia, mostly applanate sporangial columellae, frequent spirally twisted sterile outgrowths, and higher maximum growth temperature.

Type: People's Republic of China. Inner Mongolia, Aer Mountain, 47.152486°N 119.976711°E, soil under a larch tree, 16 August 1991, Z.M. Sun (**Holotype** HMAS 240173—1; **ex-holotype** culture CGMCC 3.5877 = Am-3; GenBank KC108740. **Isotypes** HMAS 240173—2–8).

Etymology: *clavatus*, referring to the shape of the aborted sporangia.

Colonies on SMA and PDA at first subfloccose, then granulate, filling the Petri dish in 6–7 (SMA) or 5–6 (PDA) days at 18°C, about 2–4 mm high, at first white then slightly grayish white, reverse dirty white. Hyphae branching, nonseptate when young, septate in age; 2–4.5 μm diam. Stolons absent. Rhizoids scanty, not opposite sporangiophores or arising from the aborted sporangia, scarcely arising from the lower part of the sporangiophores. Sporangiophores erect or recumbent, arising directly from substrate or aerial hyphae, of 2 main types: (1) bearing aborted sporangia only, (2) bearing both fertile and aborted sporangia on the same sporangiophore; main axes of the sporangiophores substraight to recurved, rarely simple, usually branched, equal or subequal in width throughout, sometimes slightly narrowed just beneath the terminal sporangia, grayish to light brownish-gray, sometimes with granular contents in the upper part, 5.5–14 μm diam. and reaching a length of 380–762 μm; primary branches 1–3, remaining simple, repeatedly branching 1-2 times, or forming aborted sporangia in a chain of 2–6. Septa usually absent, very rarely present at the branches 40–60 μm below the sporangia. Aborted sporangia also borne terminally on the main axes or branches of the sporangiophores, or repeatedly proliferating terminally or laterally forming intercalary sporangiophores between two aborted sporangia, usually not exceeding 7 in number, transferring their contents forward to form a chain of aborted sporangia until formation of a fertile sporangium, globose and 18.5–41.5 μm diam., or ovoid to ellipsoid and 23–74 × 14–32 μm, granular when young, vacuolate in age, subhyaline to gray in color. Fertile sporangia borne terminally on the main axes or branches of the sporangiophores, globose, 27.5–78 μm diam., non-apophysate, breaking and usually not dissolving, thin-walled, at first gray, then grayish-brown when mature. Columellae formed only in fertile sporangia, well developed, mostly applanate to depressed globose and (4–)9–25 × (6–)12.5–34 μm, rarely subglobose and 14–33 μm diam., light grayish-brown, often with a large and distinct collar. Sporangiospores forming only in fertile sporangia, oblong-ellipsoid, 2.5–4.5(–5.5) × 2–2.5 μm, (1–)2-guttulate, hyaline, grayish in mass, smooth, becoming vacuolate in old cultures. Sterile outgrowths abundant, mycelium-like, growing out from the tip of the aborted sporangia or from the branches of sporangiophores, spirally twisted. Chlamydospores absent. Zygospores unknown.

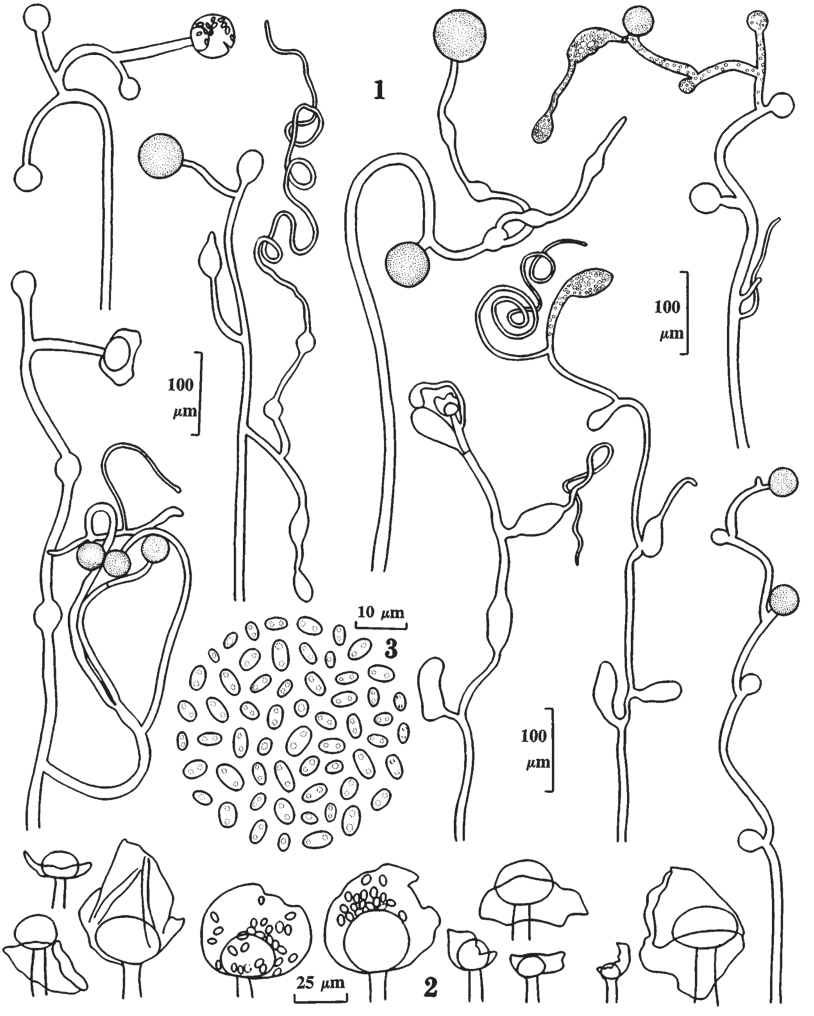

Figure 5. *Ambomucor clavatus* (AS 3.5877, = Am-3, ex-holotype). 1. Upper portions of sporangiophores, mostly with both fertile and aborted sporangia on the same sporangiophore, a few with aborted sporangia only. Note that the aborted sporangia are either subglobose or more frequently ovoid to elliptic-ovoid and spirally twisted sterile outgrowths are formed from the upper portion of the aborted sporangia or less frequently from the branches of sporangiophores. 2. Columellae of various shapes, each with a large collar. 3. Sporangiospores.

Key to the taxa of *Ambomucor*

1. Aborted sporangia globoid, ovoid to ellipsoid; columellae of the fertile sporangia mostly applanate, rarely globose to subglobose; sterile outgrowths frequent, often spirally twisted; maximum growth temperature 33°C. . . . . ***A. clavatus***
1. Aborted sporangia globose to subglobose; columellae of the fertile sporangia mostly globose to subglobose, or ovoid-ellipsoid, smaller ones applanate; sterile outgrowths absent or rare, not spirally twisted when present; maximum growth temperature 30°C **2**
2. Aborted sporangia in chains of 10(–20); sporangiophores never verticillately branched; sterile outgrowths not in zigzags, usually absent; when globose columellae reaching 60 µm diam.; sporangiospores (2.5–)3.5–8 × (1.5–)2–2.5(–3.5) µm . . . . . ***A. seriatoinflatus*** var. ***seriatoinflatus***
2. Aborted sporangia usually not exceeding chains of 6; sporangiophores sometimes verticillately branched; sterile outgrowths when present often in zigzags; when globose columellae not exceeding 42 µm diam., sporangiospores (2.5–)3.5–5 × 2–3(–4) µm . . . . . ***A. seriatoinflatus*** var. ***brevior***

Acknowledgements

The project was partially supported by the National Science Foundation of China (Nos. 31070016, 31070019 and 31370068) and the Foundation of the Knowledge Innovation Program of the Chinese Academy of Sciences (No. KSCX2-EW-J-6). Prof. Xing-zhong Liu, Director of the State Key Laboratory of Mycology, who supplied us with collections, is greatly appreciated. We also thank (both of this Laboratory) Ms Xiang-fei Zhu for inking the line drawings and Ms Hong-mei Liu for testing the maximum growth temperatures. Prof. Gerald L. Benny (University of Florida, USA) and Prof. Paul M. Kirk (Kew, UK) are thanked for reviewing this paper.

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